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SOLID WASTE SOURCE SEPARATION TEST AT VANDENBERG AIR FORCE BASE--ETC(U)
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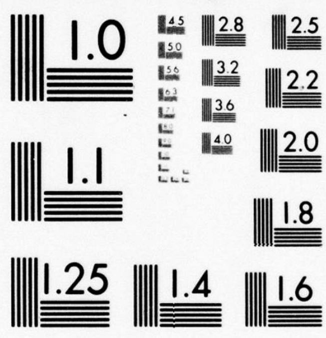

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LEVEL II

SOLID WASTE SOURCE SEPARATION TEST AT VANDENBERG AIR FORCE BASE, CALIFORNIA, PHASE II: CHARACTERIZATION OF IN-TEST SOLID WASTE MANAGEMENT SYSTEM

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DECEMBER 1978

FINAL REPORT JANUARY 1977 - MAY 1978

Approved for Public Release; Distribution Unlimited

CEEDO

CIVIL AND ENVIRONMENTAL ENGINEERING DEVELOPMENT OFFICE
(AIR FORCE ENGINEERING AND SERVICES CENTER)
TYNDALL AIR FORCE BASE
FLORIDA 32403

14 CEL-M-64-78-Ø7

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER CEEDO TR-78-49	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 SOLID WASTE SOURCE SEPARATION TEST AT VANDENBERG AIR FORCE BASE, CALIFORNIA. PHASE II. CHARACTERIZATION OF IN-TEST SOLID WASTE MANAGEMENT SYSTEM.		5. TYPE OF REPORT & PERIOD COVERED 9 Final rept. Jan [redacted]77 – May [redacted]78
		6. PERFORMING ORG. REPORT NUMBER M-64-78-07
7. AUTHOR(s) 10 Carter J. Ward [redacted] John L. Squier		8. CONTRACT OR GRANT NUMBER(s) Project Orders: 77-26 78-111
9. PERFORMING ORGANIZATION NAME AND ADDRESS CIVIL ENGINEERING LABORATORY Naval Construction Battalion Center Port Hueneme, California 93043		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Civil and Environmental Engineering Development Office Air Force Engineering and Services Center Tyndall Air Force Base, Florida 32403		12. REPORT DATE 11 Dec[redacted]78
		13. NUMBER OF PAGES 45
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 12 45p.		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available in DDC.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Solid waste, source separation, solid waste management, resource recovery.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report summarizes the impact on solid waste management operations caused by the implementation and operation of a test refuse source separation program at Vandenberg Air Force Base, California. Results reported herein will be incorporated in a waste materials recovery program guide under development by the Civil and Environmental Engineering Development Office (CEEDO).

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Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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PREFACE

This report was prepared by the Navy's Civil Engineering Laboratory, (CEL), Port Hueneme, California under Project Orders 77-26 and 78-111 with the Civil and Environmental Engineering Development Office (CEEDO), Tyndall AFB, Florida. Dr. Carter Ward and Mr. John Squier performed the study, assisted by Mr. William V. Miller. Major Robert Olfenbuttel, CEEDO, was project officer. This work was accomplished during the period from January 1977 to May 1978.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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TABLE OF CONTENTS

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SECTION I

INTRODUCTION

The Civil Engineering Laboratory (CEL) was tasked by the Air Force to evaluate the technical and economic effectiveness of source separating recoverable solid wastes through a voluntary source separation program at Vandenberg Air Force Base, California. This program was implemented by base civil engineering personnel and by a regionally oriented recycling contractor.* In addition, the study included evaluation of source separation schemes being addressed by the other military services. The results of this study will be used as a basis for developing a guide for use by other Air Force installations in evaluating existing solid waste management systems and implementing, if feasible, appropriate source separation programs. Such a guide is required to enable Air Force managers to adequately meet recently promulgated Environmental Protection Agency (EPA) mandatory requirements for solid waste source separation and resource recovery. This effort was approximately 16 months in duration and was conducted in three phases consisting of pre-test (Phase I), in-test (Phase II), and post-test (Phase III) periods.

BACKGROUND

The Department of Defense (DoD) is mandated by EPA guidelines to establish solid waste resource recovery at most military installations. Resource recovery can take the form of either source separation or the more sophisticated, highly capital intensive mechanized refuse processing; however, the absence of high waste tonnages at most, if not all, Air Force bases dictates the use of basic source separation. Firm and proven guidelines for implementation of source separation on military installations is lacking and must be developed if base managers are to avoid historic recycling failures and effectively meet the requirements of the EPA guidelines (and, concomitantly, reduce their overall solid waste management costs).

To meet these needs, a source separation test has been conducted at VAFB. This test is expected to serve as a model for developing needed DoD/Air Force solid waste source separation guidance. Regional refuse resource recovery agency participation was an integral factor in the testing.

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*Santa Barbara Resource Recovery Program (SBRR), Community Environmental Council, Inc. (CEC), Santa Barbara, California.

Reference 1 describes the Vandenberg Air Force Base program and outlines the responsibilities of each of the participating agencies.

APPROACH AND SCOPE OF CIVIL ENGINEERING LABORATORY PARTICIPATION

Overall Program

Civil Engineering Laboratory conducted a study in three phases, complementing the contracted source separation test conducted at Vandenberg Air Force Base.

Phase I of the Civil Engineering Laboratory study consisted of surveying and characterizing the pre-test solid waste management system to establish a data baseline. Phase II, concurrent with the VAFB test, was comprised of two primary tasks: (1) periodic survey and evaluation of the technical effectiveness of the source separation, and (2) assessment of the impact of source separation on the costs of waste collection and disposal. In Phase III, SCS Engineers, under contract to Civil Engineering Laboratory, compared the results with the results of other source separation tests (including those at Civil Engineering Laboratory/Naval Construction Battalion Center), and developed a summary of essential factors which should be required in a source separation program for use at military installations.

Phase I

The Phase I study, the work plan for which is described in detail in Appendix A of Reference 2, consisted of surveying and characterizing the pre-test solid waste management system at Vandenberg Air Force Base, both functionally and quantitatively. The purpose was to establish a meaningful data baseline with which the source separation test results can be compared. This effort included a detailed survey and analysis of solid waste management costs. The study also included determination of the quantities (tonnages) of solid waste materials potentially recoverable from waste-generating source types, as well as the total quantities of the waste streams for each source type from which a portion of the recyclable materials was later recovered.

Phase II

Surveys to evaluate the technical effectiveness of the source separation of refuse and its impact on the costs of refuse collection were made midway through the Vandenberg Air Force Base test (in May, June, and August 1977) and near the end of the test (in February and March 1978). These surveys consisted of operational time studies of janitorial collection of office refuse, vehicle collection of refuse from office buildings, and landfill disposal of all refuse. These surveys were supplemented by photographic surveys of the composition of residential and office refuse and by determinations of quantities (weights) and densities of office and residential refuse, both recycled and residue.

Phase III

The analysis and development of guidelines and the comparison of results of the Vandenberg Air Force Base test with those of other similar refuse source separation test programs (i.e., Camp LeJeune/Cherry Point, Naval Construction Battalion Center Port Hueneme, Ft. Meade, Camp Pendleton, and NAS Alameda) was completed by SCS Engineers under contract to Civil Engineering Laboratory and will be reported separately as a Civil Engineering Laboratory Contractor Report.

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SECTION II

SOLID WASTE MANAGEMENT SYSTEM

METHODS OF COLLECTION AND DISPOSAL

Vandenberg Air Force Base and the solid waste management system in operation at that time were studied in detail in 1974, as described in Reference 3. Although much of the 1974 information was still valid at the time of the Phase I survey, there had been some changes having significant impact on the solid waste stream and its collection and disposal. For example, there had been a 20 percent weight reduction in the solid waste disposed at the landfill, which would also indicate reductions in the collection load* and the janitorial waste collection effort. Further, the pre-test base recycling program had deteriorated, as evidenced by a significant slackening in the recycling of high-grade paper, glass, aluminum cans, and newspaper. In fact, the recoverable materials that were collected were merely being stored in a warehouse, rather than being sold or otherwise recycled. Also, some of the older collection equipment had been replaced by newer equipment, which affects the cost data.

The Phase I study resurveyed collection operations in order to provide the required up-to-date data baseline for Phase II in-test evaluation of the cost and time impact of the source separation and resource recovery program.

1. Base Collection. The base solid waste daily vehicle collection areas are approximately as shown in Figure 1. Areas 1 and 2 are each collected using one front-end loading, compacting (LoDal) truck with a two-man crew (driver and spotter assistant). Area 3, which overlaps parts of Areas 1 and 2, is collected by a hoist-and-haul truck handling one Dempster Dumpster bin at a time. Throughout the base, small facilities having 32-gallon cans are serviced on Monday and Tuesday of every other week, using a rear-loading Loader-Packer disposal truck.

Collection of recyclables during the pre-test base recycling program is described in Reference 2. Collection procedures and schedules for collection of recyclables during Phase II by the recycling contractor, Community Environmental Council, Inc. (CEC), are not included in this report but are expected to be reported by CEC as part of their documentation.

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*This was confirmed by observations by drivers of the Vandenberg Air Force Base solid waste collection vehicles.

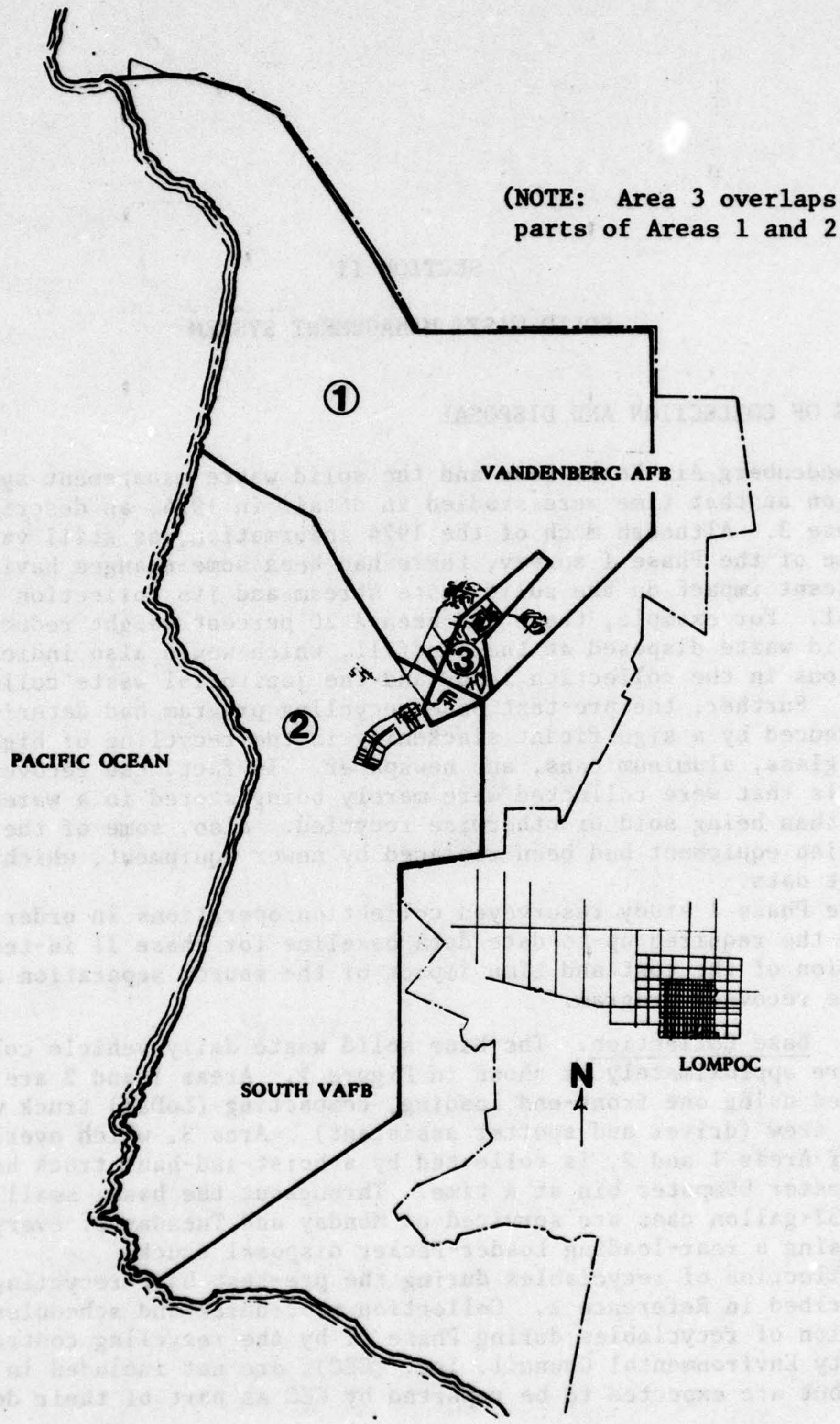

Figure 1. Vandenberg Air Force Base Solid Waste Daily Vehicle Collection Areas

The base collection equipment available for use is summarized in Table 1.

2. Residential Collection. The residential areas are served by a contractor, who uses two rear-loading compacting vehicles, as described in Reference 3. Their collection schedule has changed, however, to the following:

Monday and Thursday:	All areas on the west side of the Lompoc-Casmalia Road, except Trailer Park No. 7.
Tuesday and Friday:	All areas on the east side of the Lompoc-Casmalia Road, and Trailer Park No. 7.
Wednesday and Saturday:	No collection.

All non-recycled refuse is hauled to the base landfill. This includes not only waste collected by the base vehicles, but also that collected by the contractor from the residential areas and from other sources such as the nearby Federal Correctional Institution.

COLLECTION TRUCK TIME STUDIES

To provide a baseline for evaluating the time and cost impact of the source separation program on the normal waste collection operations, a time-and-motion study of the use of the front-loading compacting trucks (Collection Areas 1 and 2) was conducted over two one-week periods during Phase I. Similar Phase II refuse collection vehicle time studies were made during the source separation test program in August 1977 and again in February-March 1978.

Time-and-motion studies were not done for the hoist-and-haul and rear-loading vehicles because it was expected that the source separation program would have negligible impact on their operations. The operation of the hoist-haul vehicle involves only one container per trip to the landfill, and any significant but small change in the quantity of waste collected due to the separation of recyclables would not be cumulative, as it is with the front-loading trucks which load and compact the waste from 10 to 15 containers before going to the landfill. The base rear-loading vehicle serves less-used 32-gallon containers in scattered areas only once in two weeks and thus is not likely to be affected significantly.

The Phase I data sheet described in Reference 2 was also used in the Phase II study. These forms were used to record the travel times between stops, the loading times per stop (including the time to compact the load, which was done for nearly every container emptied), miscellaneous delay times (e.g., tire repairs or rest stops), and any other information which would help to properly interpret the data, such as number of containers emptied per stop, if more or less than one. The collection time study data for Phases I and II are summarized in Table 2.

TABLE 1. VANDENBERG AIR FORCE BASE SOLID WASTE COLLECTION VEHICLES

Route No.	Vehicle Number	Vehicle Type
1	75C707	LoDal
2	75C636	LoDal
1 and 2	75C637	LoDal
1 and 2	71C451	LoDal
3	73C229	Dempster Dumpster
3	67C1508	Dempster Dumpster
4	72C255	Load Packer
Bulk Loads	67B5241	1-1/2-ton stake bed

TABLE 2. SUMMARY OF VANDENBERG AIR FORCE BASE SOLID WASTE COLLECTION VEHICLE TIME STUDY RESULTS

Tasks*	Time, Minutes (Except as Noted)		
	Phase I Feb/Mar 77	Phase II Aug 77	Phase II Feb/Mar 77
Travel Between Bins			
Average total per day	161.52	166.55	167.61
Avg no. bins per day	31.9	33.0	34.6
Average per bin	5.06	5.05	4.84
Maximum	34.80	32.35	37.52
Minimum	0.28	0.29	0.48
Loading Into Truck			
Average total per day	72.98	77.77	71.57
Avg no. bins per day	28.4	31.5	32.8
Average per bin	2.57	2.47	2.18
Maximum per bin	10.41	6.87	9.19
Minimum per bin	0.30	0.50	0.34
Inspection Only			
Average total per day	2.86	2.02	(a)
Avg no. bins per day	3.5	1.5	1.8
Average per bin	0.82	1.35	(a)
Maximum per bin	2.20	1.88	(a)
Landfill Disposition			
Average per day	14.66	9.20	7.36
Avg no. trips per day	2.9	2.3	1.8
Average per trip	5.06	4.00	4.09
Maximum per trip	16.32	7.29	7.00
Minimum per trip	2.20	2.62	2.20
Delays			
Vehicle			
Avg no. per day	0.9	2.0	1.8
Average per day	17.24	22.84	33.42
Average per delay	19.44	11.42	19.10
Maximum per delay	93.00	30.58	40.00
Minimum per delay	2.35	1.78	2.70

continued

TABLE 2. CONTINUED

Tasks*	Time, Minutes (Except as Noted)		
	Phase I Feb/Mar 77	Phase II Aug 77	Phase II Feb/Mar 77
Personal			
Avg no. per day	2.5	2.0	1.5
Average per day	23.62	15.05	19.21
Average per delay	9.71	7.52	12.81
Maximum per delay	30.84	13.13	25.00
Minimum per delay	0.26	1.00	3.52
Other			
Avg no. per day	1.7	3.0	4.0
Average per day	12.37	26.08	56.04
Average per delay	6.72	8.69	14.01
Maximum per delay	36.50	26.70	90.00
Minimum per delay	0.18	1.02	0.55

(a) Inspection times not recorded.

* Above times are limited to those tasks in collection route for one truck crew. Remaining portion of day includes morning crew group meeting, truck cleaning, phone response pick ups, coffee breaks, and employee wash prior to departure.

JANITORIAL SERVICES TIME STUDIES

Another function potentially vulnerable to impact by the source separation program is the collection of solid waste by janitors as they empty wastebaskets and transfer the waste to outdoor containers. To provide a baseline for evaluating this impact, the normal (pre-test) time periods required to perform these functions were observed and recorded during Phase I. The waste handling in the administrative areas of six office buildings and that in two clubs were sampled. The administrative areas sampled, measured in square feet, represent 16 percent of the total base administrative office space provided with janitorial service under the contract. The time studies concentrated on the administrative areas becuase they are the sources of high-grade paper to be separated from the solid waste stream during the test. The office buildings were selected from the list furnished by the test recycling contractor as those of primary interest in their test.

The form described in Reference 2, facilitated the recording of the time required to complete each run. (A run was completed by the filling of the janitor's portable trash cart.) The time periods required in each run for travel to the outdoor container, emptying the cart, and returning to the area were recorded. Table 3 summarizes the results of the Phase I and II office building time studies. During Phase II, the janitorial time studies were limited to office buildings, as refuse source separation in clubs was not expected to make a significant impact on janitorial costs. Some of these data are used later in this report in determining and presenting the source segregation impact on cost of janitorial collection.

DISPOSAL OPERATIONS TIME STUDIES

Two men are employed in the landfill operation: one operator and one assistant operator. Occasionally a non-operating helper is also assigned to the area to direct traffic and perform miscellaneous tasks. The operators use two items of major equipment: one large International TD25 bulldozer and one smaller Caterpillar D6 bulldozer. The larger bulldozer is used primarily to scrape and prepare cover material (i.e., earth to be used to bury the solid waste), but it can also be used to move large amounts of brush and solid waste. The smaller bulldozer is used primarily as the landfill compactor. Its job includes the filling of cells with solid waste and covering the cells with earth. This is the vehicle which normally performs the actual landfill operation.

Phase I (pre-test) time-study data for landfill operation were taken in March 1977. Because of many mechanical equipment problems, these data are not entirely representative of actual landfill operations. The observed disposal operations are described in Reference 2.

Phase II landfill operations time studies were made in August 1977 and again in February 1978. The results of all three studies (Phase I Pre-test, Phase II Mid-test, and Phase II Late-test) are summarized in Table 4. For this comparison , the data for the pre-test and mid-test

studies were redetermined from the original log sheets after reinterpretation on the basis of a common definition of productive time. As reinterpreted, the operator's time spent in management activities was considered as productive time, as was the time spent by the assistant operator in discussing the work with the operator.

TABLE 3. SUMMARY OF VANDENBERG AIR FORCE BASE OFFICE BUILDING JANITORIAL SOLID WASTE COLLECTION TIME STUDY RESULTS

Bldg No.	Floor No.	No. Runs	Average Times Per Run, Minutes					No. Wastebaskets	No. Rooms	Coll. Time-Min (2)		Tot. Run Time-Min (3)		Total Collection Time-Hr
			Collection (1)	To Bin	Unloading	Return	Total			Per WB	Per RM	Per WB	Per RM	
PHASE I - February/March 1977														
10577	1	3	5.29	0.89	0.48	0.89	7.54	48	8 hls (4)	0.33	1.98 (4)	0.47	2.83 (4)	0.38
7000	3	3	13.47	2.39	0.86	1.86	18.58	125	88	0.32	0.46	0.45	0.63	0.93
8500	1	4	12.99	0.75	0.31	0.75	15.02	182	135	0.29	0.38	0.33	0.45	1.00
6525	1	3	12.82	1.62	0.64	1.48	16.56	150	64	0.26	0.60	0.33	0.78	0.83
861	1	2	8.52	0.58	0.20	0.33	9.63	82	47	0.21	0.36	0.23	0.41	0.32
PHASE II - August 1977														
10577	1	3	3.77	0.58	0.33	0.66	5.34	39	25 (4)	0.29	0.45 (4)	0.41	0.64 (4)	0.27
7000	3	1	23.83	3.35	0.33	1.93	29.44	86	84	0.28	0.28	0.34	0.35	0.49
8500	1	3	16.00	0.73	0.16	0.52	17.41	142	103	0.34	0.47	0.37	0.51	0.87
6525	1	2	10.50	0.83	0.39	0.73	12.45	98	41	0.21	0.51	0.25	0.61	0.42
861	1	2	10.09	1.12	0.25	0.80	12.26	75	41	0.27	0.49	0.33	0.60	0.41
PHASE II - February/March 1978														
10577	1	1	11.11	1.54	0.25	0.56	13.46	28	17 (4)	0.40	0.65 (4)	0.40	0.65 (4)	0.22
7000	3	1	25.13	8.71	0.81	0.57	35.22	72	47	0.35	0.53	0.49	0.75	0.59
8500	1	2 (5)	29.88	0.76	0.31	0.77	31.72	169	105	0.18	0.28	0.19	0.30	1.06
6525	1	1 (6)	17.89	1.82	1.15	0.51	21.37	59	17	0.30	1.05	0.36	1.26	0.36
861	1	1	12.79 (7)	0.58	0.17	0.24	13.78	51	34	0.25	0.38	0.27	0.41	0.23

NOTES:
(1) In most cases, collection time included emptying and wiping ash trays.
(2) Collection Time = (No. Runs) x (Average time per run for "Collection").
(3) Total Run Time = (No. Runs) x (Average time per run for "Total").
(4) Bldg. No. 10577 received class C-3 service: the wastebaskets had been placed in the halls by the users.
(5) Second of two runs (1st run missed); Janitor's comment: light night, usually 3 loads.
(6) First of two runs; Second run collected only, not dumped.
(7) Second run: 4.41; Average of two runs = 8.60 min.

TABLE 4. VANDENBERG AIR FORCE BASE LANDFILL OPERATION TIME STUDY RESULTS, COMPARATIVE SUMMARY OF PHASES I AND II

Phase	Date	Day	Operator			Operator's Machine		Assistant Operator			Assistant's Machine		Helper		
			Prod.	Tot.	Percent	Prod.	Percent	Prod.	Tot.	Percent	Prod.	Percent	Prod.	Tot.	Percent
I pre	3/8/77	Tue	273	320	85	188	59	--	-	-	--	-	52	320	16
	3/10/77	Thu	222	265	84	221	83	--	-	-	--	-	--	-	-
	3/11/77	Fri	56	60	93	154	95	157	162	97	58	97	--	-	-
	Avg %				87		79			97		97			16
II mid	8/2/77	Tue	300	330	91	115	35	297	327	91	197	60	--	-	-
	8/4/77	Thu	330	360	92	105	29	356	361	99	327	91	--	-	-
	8/8/77	Mon	302	354	85	200	56	139	149	93	106	71	152	385	39
	Avg %				89		40			94		74			39
II end	2/7/78	Tue	123	286	43	86	30	--	-	-	--	-	--	-	-
	2/9/78	Thu	86	304	28	20	7	--	-	-	--	-	--	-	-
	2/13/78	Mon	124	372	33	73	20	--	-	-	--	-	--	-	-
	2/17/78	Fri	322	358	90	221	62	214	327	65	--	-	--	-	-
	Avg %				90		62			65		-			-
Avg Percent PHASE I					87		79			97		-			-
Avg Percent PHASE II					90		51			-		-			-

SECTION III

SOLID WASTE WEIGHT SURVEYS

PHASE I

A significant part of the pre-test survey was the measurement of waste quantities generated at Vandenberg Air Force Base by each source type. During two typical one-week periods, solid waste collected by the base vehicles and by those of the residential collection contractor was weighed. To determine the weights of waste generated by each source type, the collection vehicles were routed selectively to only one source type per weigh-in. The drivers were asked to collect the waste from only one source type at a time, weigh it, and dispose of it at the base landfill before proceeding to collect from another source type. The source types are as defined in Appendix A of Reference 2.

The observed weights of solid waste from each source type each day of the two-week survey were reported in Reference 2. These data are summarized in Table 5, and the data for offices and residences are included in Table 6. It was found that source types A (offices) and E (residences), which were of particular interest in this study, produced 51 percent of the waste by weight.

In addition to the source-type-oriented weight survey, the separated recyclable materials collected from the entire base in a typical one-week period were weighed. These data (included in Table 7), when added to the weight survey data that excluded the recyclables, resulted in an increase in total quantity of waste from 128.3 to 131.2 tons per week.

PHASE II

Similar weight surveys were conducted in August 1977 and in February-March 1978, for source types A and E (offices and residences) only, as these were of particular concern in the Vandenberg Air Force Base test. The results of these measurements, for both recovered recyclables and residue, are summarized in Tables 6 and 7.

ANALYSIS OF INCREASE IN WEIGHT OF FEBRUARY-MARCH 1978 OFFICE REFUSE

During the February-March 1978 survey of VAFB office solid waste remaining after source separaton, a three- or four-fold weight increase was observed. The causes of this increase were not obvious, which

TABLE 5. SUMMARY OF VANDENBERG AIR FORCE BASE PHASE I SOLID WASTE QUANTITIES BY SOURCE TYPE

Source Type	Class	Weekly Quantity of Solid Waste (tons)	Percentage
Offices	A	16.0*	12.2
Warehouses	B	6.3	4.8
Shops	C	10.6	8.1
Missile Operations	D	8.8	6.7
Residences	E	51.0**	38.9
Services	F1	27.2	20.7
Clubs	F2	6.4	4.9
Dormitories	G	4.9	3.7
Weekly Total		131.2	100.0

*Includes 1.7 tons per week of high-grade paper delivered to recycling center.

**Includes 1.2 tons per week of mixed glass delivered to recycling center.

NOTE: According to information from Mr. E. P. Riggs, Vandenberg Air Force Base, CES/Refuse Collection, 80 percent of recycled mixed glass came from residences.

TABLE 6. SUMMARY OF VANDENBERG AIR FORCE BASE WEEKLY SOLID WASTE WEIGHT SURVEY DATA

Source Type	Sub-Totals, lb		Weekly Total	
	Refuse	Recyclables	Pounds	Tons
PHASE I - February/March 1977				
Offices (A)	28,534	3,464	31,998	16.0
Residences (E)	99,540	2,484	102,024	51.0
PHASE II - August 1977				
Offices (A)	24,380	12,650	37,030	18.5
Residences (E)	109,320	3,810	113,130	56.6
PHASE II - February/March 1978				
Offices (A)	86,820 (24,380)*	25,759	112,579 (50,134)	56.3 (24.1)
Residences (E)	99,240	4,840	104,080	52.0

*The excessive weight of office refuse observed in the February/ March 1978 survey is presented. However, in order to avoid the errors due to the water present, the corresponding weight from the August 1977 survey was substituted in the calculations for February/March 1978 (i.e., an office refuse weight of 24,380 pounds/week was used in place of the excessive 86,820 pounds/week).

TABLE 7. SUMMARY OF WEEKLY WEIGHTS OF RECOVERED RECYCLABLE MATERIALS

Source Type	Commodity	Weekly Total	
		Pounds	Tons
PHASE I - February/March 1977			
Office Buildings (A)	Computer Printout	1,450	0.7
	Computer Cards	2,014	1.0
	Sub-Total	3,464	1.7
Residences (E)	Aluminum Cans	45	0.02
	Mixed Glass	2,439	1.2
	Sub-Total	2,484	1.2
PHASE II - August 1977			
Office Buildings (A)	Computer Printout	4,420	2.2
	Computer Cards	2,410	1.2
	White Ledger	2,240	1.1
	Colored Ledger	2,700	1.4
	Cardboard	880	0.4
	Sub-Total	12,650	6.3
Residences (E)	Aluminum Cans	162	0.1
	Mixed Glass	2,228	1.1
	Newsprint	1,420	0.7
	Sub-Total	3,810	1.9
PHASE II - February/March 1978			
Office Buildings (A)	Computer Printout	4,205	2.1
	Computer Cards	1,440	0.7
	White Ledger	5,554	2.8
	Colored Ledger	680	0.3
	Cardboard	13,880	6.9
	Sub-Total	25,759	12.8
Residences (E)	Aluminum Cans	225	0.1
	Mixed Glass	0	0
	Newsprint	4,615	2.3
	Sub-Total	4,840	2.4

called for an investigation and analysis. During the February 1977 survey prior to the CEC program, 28,534 pounds per week of solid waste were collected from the office areas (Table 6). This did not include the 3,464 pounds per week of high-grade paper that were pulled from the office areas for recycling. During the August 1977 survey which was after CEC initiated their source separation program, 24,380 pounds per week of solid waste were collected from the office areas. This again did not include the 12,650 pounds per week of recyclable material recovered. However, during the February-March 1978 survey, 86,820 pounds per week of solid waste were collected from the office areas; this again did not include the 25,760 pounds per week of recyclable materials collected separately. During these same surveys, the residential waste collected did not significantly change (i.e., 99,540 pounds per week for February-March 1977; 109,320 pounds per week for August 1977; and 99,240 pounds per week for March 1978).

The possible causes of the observed increase in office refuse weight include: (1) people cleaning out in preparation for the Annual Commander's Annual Facilities Inspection (CAFI) scheduled for 10 April 1978; (2) trash held back by janitors because of rain during previous weeks, then dumped during the survey week; (3) people generating more waste due to cleaning out of offices while being confined by the rain; (4) heavier trash due to being wet from the rain; and (5) water in the bottom of bins and trucks with the refuse. Of these possible causes, the first two are believed to have had little impact. The inspection is not considered a factor since the survey preceded it by five weeks. Trash held back and later dumped during the survey week is not considered a factor becuase there is no storage space for trash in office buildings. The third and fourth possible causes are believed to be probable secondary factors but not major contributions. The discard of refuse by people confined by the rain is considered as a minor contributing factor, but there is no way to quantify it. Wet trash increased the density by a factor of 1.3 (4.58 lb/cu ft in August 1977 to 5.95 lb/cu ft in March 1978). However, the 1.3 density factor increase cannot account for the 3.6 ratio increase in gross weight of the average truck load.

Water in bins and trucks is considered the major contributing factor causing the increase in refuse weight measurements. The weather during the survey period was characterized by heavy rainfall. It is hypothesized that water not only soaked much of the trash, but it also accumulated in the bottoms of the bins and was dumped with the trash into the compactor trucks, where it accumulated and was weighed with the load. Observations* by the Vandenberg Air Force Base refuse collection personnel during typical rainy weather support this hypothesis. It is further confirmed by several calculations based on the survey results.

The 10-cubic-yard bins have an 85-gallon sump in the bottom.* Water filling this sump, to a depth of approximately 3 inches, would weigh 709 pounds (85 gallons x 8.35 pounds per gallon). The compactor trucks are sealed to a height of 18 inches above the floor.* The truck bed is approximately 8 feet wide by 16 feet long which would allow an

*Per Mr. Everette Riggs, VAFB Refuse Collection Crew.

accumulation of water to 11,987 pounds. The August 1977 average dry truck load was 2,300 pounds. If this value is multiplied by 1.3 (the measured density increase of the wet trash), it would give a truck load weight of 2,990 pounds. The average truck load during the March 1978 survey was more than 8,400 pounds. This indicates a possible 8-inch depth of water in the truck or 5,410 pounds of water. This additional water weight is realistic. In the February-March 1978 survey an average of 14.6 bins was collected per truck load which indicates that each bin contained an average of 371 pounds or a little over 1.5 inches of water in the bottom sump of each bin.

The fact that residential waste did not increase during the rains is believed to be due to those containers having a more watertight lid and/or the containers being stored in the garage. In regard to the measured decrease in trips to the office building outdoor containers by the janitors plus the measured reductions in quantity of waste baskets emptied during the February-March survey (see cost avoidance section for details), these results are believed also to be attributable to the rains. The janitors simply packed their portable containers more densely to reduce the number of outdoor trips. Similarly, those waste basket containers with little refuse quantity were not emptied in hopes that the next day would clear up. However, these reductions give more evidence that the office solid waste generation did not actually have a three-fold weight increase. The increase of approximately 12,000 pounds per week of recyclable materials from the previous August 1977 survey is attributable to additional cardboard. The August 1977 data indicate that only 880 pounds per week of cardboard was collected as compared to 13,880 pounds per week collected during the February-March 1978 survey. The February-March 1978 cardboard is believed to be the result of a large shipment or accumulated warehouse storage. In conclusion, it is believed that if the office disposable waste for February-March 1978 is assumed to be the same as for March 1977, the results should be reasonably close to what actually happened.

SECTION IV

SOLID WASTE COMPOSITION SURVEYS

PROCEDURES

The solid waste composition surveys were conducted by photographing random samples of waste from both the residential cans and the outdoor containers (LoDal). These photographs made possible the application of a photo-sort technique (Reference 4) in which the color slides are projected onto a rectangular grid, and the composition (e.g., glass, paper, aluminum, etc.) of the object at each grid intersection is identified and recorded. The percentages by volume of the various waste constituents of interest, as determined by the photogrid technique, were used along with the appropriate bulk densities to calculate the weight distribution of the various constituents (waste categories). The calculation procedure used is presented in detail in Reference 2.

The two figures for each refuse category, i.e., the weight (tons per week) of recyclables recovered from the waste stream and the weight (tons per week) of recyclables left in the waste stream (from the photo-sort analysis), provide a basis for calculating the separation effectiveness (percent) for each refuse category.

RESULTS

Tables 8 and 9 present the separation effectiveness for August 1977 (mid-test) and February-March 1978 (late-test), determined by the above method.

DEFENSE OF THE PHOTO-SORT TECHNIQUE

In this work, considerable data were gathered using the photo-sort technique. When the project began, this technique was believed to be the most cost-effective procedure for measuring solid waste composition. However, a July 1978 report (Reference 5) distributed by the Army concludes that this photo-sort technique cannot be used reliably to fractionate a solid waste stream by constituent mass. Their reasoning is that constituent bulk densities are not constant. Experiments conducted by CERL proved that density measurements from one waste sample cannot be used to accurately estimate mass fractions of another based on photographic information alone. Additionally, a photograph of as-discarded waste

TABLE 8. VANDENBERG AIR FORCE BASE SOLID WASTE COMPOSITION DATA WEEKLY QUANTITIES OF RECYCLABLES AND EFFECTIVENESS OF SOURCE SEPARATION, AUGUST 1977

Refuse Category	Recyclables in Normal Waste(1) (tons/week)	Recovered Recyclables(1) (tons/week)	Separation Effectiveness (%)
A. Office Buildings			
Computer Cards	1.31	1.21	92
Computer Printout	5.18	2.21	43
White Ledger	4.25	1.12	26
TOTAL	10.74	4.54	--
OVERALL	---	---	42
B. Residences - Officers			
Newspapers	0.12	0.10	83
Aluminum Cans	0.16	0.02	13
Mixed Glass(2)	0.60	0.17	28
TOTAL(2)	0.28	0.12	--
OVERALL(2)	---	---	43
C. Residences - Enlisted			
Newspapers	0.73	0.61	84
Aluminum Cans	0.42	0.06	14
Mixed Glass(2)	3.33	0.94	28
TOTAL(2)	1.15	0.67	--
OVERALL(2)	---	---	58

NOTES:

(1) The weight of the recyclables in the normal waste was the sum of the measured weights of the recovered recyclables and the calculated weights of the recyclables left in the waste (based on photosort data). For residences, the weights of the recovered recyclables were distributed between officers and enlisted personnel in proportion to the photosort distribution of unrecovered recyclables; and the weight of mixed refuse (not source separated) was distributed between officers and enlisted personnel in proportion to their respective occupancy of family housing units.

(2) Data obtained from mixed glass are shown here but were not included in the "total" or "overall" calculations, so that these data would be comparable to the corresponding data for February/March 1978. This was done because, prior to the February/March 1978 survey, glass had been deleted from the list of items being separated for recycling.

TABLE 9. VANDENBERG AIR FORCE BASE SOLID WASTE COMPOSITION DATA WEEKLY QUANTITIES OF RECYCLABLES AND EFFECTIVENESS OF SOURCE SEPARATION, FEBRUARY/MARCH 1978

Refuse Category	Recyclables in Normal Waste[(1)] (tons/week)	Recovered Recyclables[(1)] (tons/week)	Separation Effectiveness (%)
A. Office Buildings[(2)]			
Computer Cards	0.76	0.72	95
Computer Printout	3.04	2.10	69
White Ledger	6.95	2.78	40
TOTAL	10.75	5.60	--
OVERALL	---	---	52
B. Residences - Officers			
Newspapers	0.92	0.84	91
Aluminum Cans	0.06	0.02	33
Mixed Glass[(3)]	0.38	0	0
TOTAL[(3)]	0.98	0.86	--
OVERALL[(3)]	---	---	88
C. Residences - Enlisted			
Newspapers	1.61	1.47	91
Aluminum Cans	0.29	0.09	31
Mixed Glass[(3)]	3.41	0	0
TOTAL[(3)]	1.90	1.56	--
OVERALL[(3)]	---	---	82

NOTES:

(1) The weight of the recyclables in the normal waste was the sum of the measured weights of the recovered recyclables and the calculated weights of the recyclables left in the waste (based on photosort data). For residences, the weights of the recovered recyclables were distributed between officers and enlisted personnel in proportion to the photosort distribution of unrecovered recyclables, and the weight of mixed refuse (not source separated) was distributed between officers and enlisted personnel in proportion to their respective occupancy of family housing units.

NOTES (continued):

(2) The excessive weight of office refuse observed in the February/March 1978 survey is presented in Table 6. However, in order to avoid the errors due to the water present, the corresponding weight from the August 1977 survey was substituted in the calculatons for February/March 1978 (i.e., an office refuse weight of 24,380 pounds/week was used in place of the excessive 86,820 pounds/week).

(3) Data obtained for mixed glass are shown here but were not included in the "total" or "overall" calculations, so that these data would be comparable to the corresponding data for February/March 1978. This was done because, prior to the February/March 1978 survey, glass had been deleted from the list of items being separated for recycling.

will not reliably include all the constituents, because only the surface data are recorded. Materials not captured in the photograph which are buried beneath the surface, are overlooked. These are strong arguments, but they are not believed to be all-conclusive.

Regarding materials not in a photograph because they are buried beneath the surface, the CEL/VAFB surveys provided for photographs to be taken at different times during janitor loading of the bins in order to look at different levels as the bins were filled. This is a variation of the original photo-sort technique, and no statistical analysis exists to show how many surfaces or levels need to be sampled to produce a result of acceptable confidence level. This analysis is needed. However, without it, this particular point cannot be argued either way. Also, if a solid waste survey were completed using a very accurate technique for any given day, how reliably could that data predict the next day's composition?

Generally, solid waste composition surveys are conducted to acquire approximate data to guide installations in evaluating existing solid waste management systems and/or to predict the outcome of proposed new systems. Solid waste composition changes, not only from one building to another at any given facility, but from day to day, month to month, and year to year. It has not been determined just what the fundamental frequency, or periodicity or variability is, i.e., daily, weekly, monthly, seasonally, or annually. No known published information was found that even attempted to predict a first harmonic. The Civil Engineering Laboratory/Vandenberg Air Force Base surveys were not affected by such a high frequency as day-to-day variability since they extended over a full week and were conducted daily. However, they were sensitive to low frequencies. This is why CEL conducted composition surveys and weight or volume surveys simultaneously because of week-to-week changes. Besides, new packaging materials are continually being added to the waste stream. This is not to say that because solid waste composition is such a highly variable parameter, accuracy is not important. The objective, in this regard, for this report was to acquire as accurate data as possible within a given budget. According to CERL's report (Reference 5), hand sorting of solid waste costs almost 12 times as much in labor to complete as a photo-sort for a military installation generating 20 tons/day of solid waste. As a result, one may ask, is it better to measure a highly limited number of samples very accurately and assume such a sample is representative of the whole installation, or to measure a larger number of samples (i.e., 12 times as many) with a method having less accuracy.

The data gathered and the results of the analysis of those data appear to represent a highly believable and logical tabulation of what occurred in the Vandenberg Air Force Base solid waste stream during the data gathering period. Additionally, because the photo-sort technique measures the constituent volume fraction visually without weighing, the heavy rains which drenched the office waste and spoiled its weight data did not make that data useless. By assuming that values of the office waste quantity were the same as in the previous survey, reasonable

results in the data analysis were achieved. Hand sorting and weighing of water-soaked solid waste is believed to be more inaccurate in determining virgin constituent mass fraction.

A minimum of 80 samples were analyzed for each survey using the photo-sort technique. For the August 1977 survey of office waste, the refuse volume percentage of white ledger ranged from a low of zero percentage for one sample to a high of 57 percent for another sample. The mean for all the samples was calculated to be 13 percent, and the standard deviation was 14 percent. As a result, the true mean for the refuse volume percentage of white ledger for all the Vandenberg office waste should fall between 11 percent and 15 percent for an 80 percent confidence level (Reference 6).

In conclusion, results presented in this report, based on the photo-sort technique as employed by CEL, are believed to be adequately accurate for meeting the objectives of this project.

SECTION V

ANALYSIS OF COST AVOIDANCE POTENTIAL

This section describes an approach which may be used to estimate the cost avoidance potential resulting from a decrease in waste flow due to removal of recyclable materials. The particular case chosen to illustrate this approach is office refuse collection, handling, and disposal. However, a similar approach can be applied to collection, handling, and disposal of wastes from other sources (e.g., shops, warehouses, clubs, and so forth).

The symbols used in the analysis for office wastes are defined in Table 10.

DEVELOPMENT OF EQUATIONS FOR COST AVOIDANCE POTENTIAL FOR DISPOSABLE OFFICE WASTES

General Equation. The costs associated with office waste are those of wastebasket ownership; janitorial collection labor; outdoor container ownership and maintenance; truck collection labor; collection truck ownership and maintenance; and landfill labor, equipment (ownership and maintenance), and land. If a source separation program is introduced, there will be added costs of administering and maintaining an effective program. Considering these elements, the annual cost avoidance potential resulting from a decrease in office waste flow due to removal of recyclables can be expressed as:

$$P_t = P_w + P_j + P_o + P_c + P_v + P_l + P_e + P_r \quad (1)$$

Equations for the individual elements making up this equation are derived in the following paragraphs.

It should be noted that this equation accounts only for the costs associated with the disposable office waste and does not account for costs for implementing the separation program. This is because such costs are more properly associated with the recyclable waste.

Wastebasket Ownership, P_w. The first point of entry in the office space for refuse is the wastebasket. The annual cost avoidance potential for wastebaskets is the difference in cost for all wastebaskets provided without and with implementation, which can be expressed as:

TABLE 10. NOMENCLATURE AND UNITS FOR ANALYSIS OF OFFICE WASTE COST AVOIDANCE POTENTIAL

Symbol	Definition*	Units
C_c	Annual cost for truck collection labor	\$/yr
C_e	Life cycle cost for landfill equipment ownership and maintenance	\$/yr
C_j	Cost for janitorial collection labor	\$/yr
C_l	Cost for landfill labor	\$/yr
C_o	Life cycle cost of outdoor containers ownership and maintenance	\$/yr
C_r	Use cost of landfill real estate	\$/yr
C_v	Life cycle cost of collection trucks ownership and maintenance	\$/yr
C_w	Life cost of wastebaskets ownership	\$/yr
N	Defined as $N = 1 - T_{wi}/T_{wo} = T_{ri}/T_{wo} = T_{ri}/(T_{ri} + T_{wi})$	Dimensionless
P_c	Cost avoidance potential, truck collection labor	\$/yr
P_e	Cost avoidance potential, landfill equipment ownership and maintenance	\$/yr
P_j	Cost avoidance potential, janitorial collection labor	\$/yr
P_l	Cost avoidance potential, landfill labor	\$/yr
P_o	Cost avoidance potential, outdoor containers ownership and maintenance	\$/yr
P_r	Cost avoidance potential, landfill real estate	\$/yr
P_t	Cost avoidance potential, total	\$/yr
P_v	Cost avoidance potential, collection trucks ownership and maintenance	\$/yr
P_w	Cost avoidance potential, wastebaskets ownership	\$/yr
T_r	Weight of recyclable waste removed from waste stream	lb/week
T_w	Weight of refuse collected from wastebaskets	lb/week
Second Subscript:		
i	With separation implemented	--
o	Without separation implemented	--

*For office waste only.

$$P_w = C_{wo} - C_{wi} \tag{1}$$

Assuming that the number of wastebaskets required is in constant proportion to the quantity of waste disposed, then

$$C_{wi} = C_{wo} T_{wi}/T_{wo} \tag{2}$$

Substituting Equation (2) into Equation (1) gives

$$P_w = C_{wo} (1 - T_{wi}/T_{wo}) = C_{wo}N \tag{3}$$

Janitorial Collection Labor, P_j. The first office refuse handling labor is performed by the janitors. They empty the wastebaskets into their portable mobile containers and transport the waste to the outdoor containers, where it is deposited. The cost avoidance potential for this labor can be expressed as:

$$P_j = C_{jo} - C_{ji} \tag{4}$$

Assuming that the number of wastebaskets emptied and the number of runs to the outdoor container are directly proportional to the quantity of waste disposed, then

$$C_{ji} = C_{jo} T_{wi}/T_{wo} \tag{5}$$

Substituting Equation (5) into Equation (4) gives

$$P_j = C_{jo} (1 - T_{wi}/T_{wo}) = C_{jo}N \tag{6}$$

Outdoor Container Ownership and Maintenance, P_o. The second stationary container in which the office refuse is stored temporarily is the outdoor container. The cost avoidance potential for ownership and maintenance of these containers is:

$$P_o = C_{oo} - C_{oi} \tag{7}$$

Assuming that the number of outdoor containers required is directly proportional to the quantity of waste disposed, then

$$C_{oi} = C_{oo} T_{wi}/T_{wo} \tag{8}$$

Substituting Equation (8) into Equation (7) gives

$$P_o = C_{oo} (1 - T_{wi}/T_{wo}) = C_{oo}N \tag{9}$$

Truck Collection Labor, P_c. The truck collection labor force operates the vehicles that empty the outdoor containers and transport the waste to the landfill. The cost avoidance potential for truck collection labor is:

$$P_c = C_{co} - C_{ci} \tag{10}$$

Assuming that this labor cost is directly proportional to the number of outdoor containers serviced, and that the number of outdoor containers serviced is directly proportional to the quantity of waste disposed, then

$$C_{ci} = C_{co} T_{wi}/T_{wo} \tag{11}$$

Substituting Equation (11) into Equation (10) gives

$$P_c = C_{co} (1 - T_{wi}/T_{wo}) - C_{co}N \tag{12}$$

Collection Truck Ownership and Maintenance, P_v. Use of vehicles to collect the waste and transport it to the landfill incurs a number of expenses, including vehicle acquisition, depreciation, and maintenance. The cost avoidance potential associated with the collection trucks is:

$$P_v = C_{vo} - C_{vi} \tag{13}$$

If it is assumed that the collection trucks carry the same refuse loads per trip to the landfill before and after implementation, then the number of trucks required is directly proportional to the quantity of waste disposed, which means that:

$$C_{vi} = C_{vo} T_{wi}/T_{wo} \tag{14}$$

Substituting Equation (14) into Equation (13) gives

$$P_v = C_{vo} (1 - T_{wi}/T_{wo}) = C_{vo}N \tag{15}$$

The assumption that the number of vehicles is the same before and after implementation, but that use of each vehicle is in direct proportion to the quantity of waste disposed, gives approximately the same result as Equation (15).

Landfill Operating Labor, P_l. The cost avoidance potential for landfill labor is:

$$P_l = C_{lo} - C_{li} \tag{16}$$

Assuming that the cost of operating labor for landfill equipment is directly proportional to the quantity of waste disposed, then

$$C_{li} = C_{lo} T_{wi}/T_{wo} \qquad (17)$$

Substituting Equation (17) into Equation (16) gives

$$P_l = C_{lo} (1 - T_{wi}/T_{wo}) = C_{lo}N \qquad (18)$$

Landfill Equipment Ownership and Maintenance, P_e. Expenses for acquisition, depreciation, and maintenance are associated with the landfill equipment. The cost avoidance potential for ownership and maintenance of this equipment is:

$$P_e = C_{eo} - C_{ei} \qquad (19)$$

Each piece of equipment is capable of doing the same work in the same time before and after implementation. Therefore, the quantity of equipment can be reduced in direct proportion to the reduction in waste disposed, which means that:

$$C_{ei} = C_{eo} T_{wi}/T_{wo} \qquad (20)$$

Substituting Equation (20) into Equation (19) gives

$$P_e = C_{eo} (1 - T_{wi}/T_{wo}) = C_{eo}N \qquad (21)$$

Alternatively, the same numbers of equipment could be retained, but the equipment operating hours per unit time could be reduced in direct proportion to the reduction in solid waste disposed. This would extend equipment life, and give approximately the same result as Equation (21).

Landfill Real Estate, P_r. The cost avoidance potential for use of real estate for the landfill is:

$$P_r = C_{ro} - C_{ri} \qquad (22)$$

The real estate required per ton of refuse disposal is constant. Therefore,

$$C_{ri} = C_{ro} T_{wi}/T_{wo} \qquad (23)$$

Substituting Equation (23) into Equation (22) gives

$$P_r = C_{ro} (1 - T_{wi}/T_{wo}) = C_{ro}N \qquad (24)$$

APPLICATION OF EQUATIONS WITH VANDENBERG AIR FORCE BASE DATA

Data Inputs for Office Waste. Table 11 summarizes the values measured for office waste before and during the source separation experiment at Vandenberg Air Force Base. Because all the cost terms used in the equations (i.e., C_{ij}) are annual cost, some of the data documented in Reference 2 needed to be converted. These conversion equations are listed under "Value for Vandenberg Air Force Base Office Waste" in Table 11. For example, the quantity C_{co} is the annual vehicle collection labor cost for collecting office waste. Page 10 of Reference 2 gives the hourly labor rate of the collection crew and supervision. To acquire the annual labor cost for vehicle base collection, the individual labor rate was multiplied by the number of hours of each man used annually for collection, holidays, and vacation (i.e., 2,080 hours per year). The proportion of this cost used for office waste collection was assumed to be directly proportional to the ratio of office waste tonnage collected to the total base tonnage collected by the same vehicle. From Table 11 of Reference 2, 14.3 tons per week of office waste was collected and 78.5 tons of total base waste was collected. The 78.5 tons per week was determined by subtracting the residential waste and recycled materials (which are not collected by the Air Force collection trucks) from the total base generation. The same ratio was also used for calculating the proportional cost for C_{vo}. The values C_{eo}, C_{lo}, and C_{ro} are related to the landfill. The proportion of the landfill cost used for disposal of office waste was also assumed to be directly proportional to the ratio of office waste disposed to the total waste disposed at the landfill, where the total waste disposed at the landfill includes the residential waste. As a result, the office waste to total waste ratio used was (14.3)/(128.3), wherein the 128.3 tons per week was determined by subtracting the recyclable materials pulled from the total waste stream.

In addition to converting the cost terms into annual cost, the janitorial cost for trashing per square foot was altered from the \$0.00420/square foot/month, documented in Reference 2, to \$0.00454/square foot/month. This cost item was changed because some of the office buildings surveyed in Phase II were not monitored identically to Phase I. As a result, some data were eliminated, which altered slightly the comparable cost per square foot per month.

As discussed earlier and as indicated in the Phase I data tabulated in Table 6, there was some partial source segregation of office wastes prior to Phase II. If this initial segregation is not taken into account, the value of N for August 1977 would be 0.34 as shown in Table 11. However, if one accounts for the recyclables already being removed and normalizes the Table 6 data to a constant weight of office refuse plus recyclables produced per week, then the value of N for August 1977 would be 0.26. Since it is not known to what extent cost avoidances had already resulted from the partial segregation effort, it can be concluded only that the data should tend to confirm a value of N somewhere in the range of 0.26 to 0.34. Therefore, numerical results were calculated for both these values of N.

TABLE 11. SUMMARY OF VALUES MEASURED FOR OFFICE WASTE AT VANDENBERG AIR FORCE BASE

Quantity	Value for Vandenberg Air Force Base Office Waste	Source of Value for Vandenberg Air Force Base Office Waste
C_{co}	{[$8.66/hr + 5($6.69/hr) + $6.45/hr] (2,080 hr/yr) + 0.7($5,196/yr)} (14.3/78.5) = $19,088/yr	Page 10 of Reference 5
C_{eo}	($42,640/yr)(14.3/128.3) = $4,753/yr	Table 27 of Reference 5
C_{jo}	($0.00454/sq ft-mo)(1,084,000 sq ft)(12 mo/yr) = $59,056/yr	Page 9 of Reference 5
C_{lo}	($34,547/yr)(14.3/128.3) = $3,851/yr	Table 27 of Reference 5
C_{oo}	$31,096/yr + $13,244/yr = $44,340/yr	Table 26 of Reference 5
C_{ro}	($0.1333/ton)(6,671.6 tons/yr)(14.3/128.3) = $99/yr	Page 11 of Reference 5
C_{vo}	($41,863/yr)(14.3/78.5) = $7,626/yr	Table 25 of Reference 5
C_{wo}	$714/yr	Table 26 of Reference 5
N	0.34	$T_{ri}/(T_{ri} + T_{wi})$
T_{ri}	12,650 lb/week	Aug 77 data, Table 6 herein
T_{wi}	24,380 lb/week	Aug 77 data, Table 6 herein

Numerical Results for Office Waste Cost Avoidance Potential. Substitution of the input values given in Table 11 into the equations for the individual elements and summing the individual elements to obtain the total cost avoidance potential gives results as follows:

	N = 0.34	N = 0.26
P_w =	$ 243/yr	$ 186/yr
P_j =	$20,079/yr	$15,355/yr
P_o =	$15,076/yr	$11,529/yr
P_c =	$ 6,490/yr	$ 4,963/yr
P_v =	$ 2,593/yr	$ 1,983/yr
P_l =	$ 1,309/yr	$ 1,001/yr
P_e =	$ 1,616/yr	$ 1,236/yr
P_r =	$ 34/yr	$ 26/yr
P_t =	$47,440/yr	$36,279/yr

DISCUSSION OF NUMERICAL RESULTS FOR OFFICE WASTE COST AVOIDANCE POTENTIAL

The office waste cost avoidance potential calculated in the preceding section is an estimate of the maximum cost avoidance that could be achieved. It will be fully realized only if actions can be and are taken to reduce costs in proportion to the reductions in the quantity of waste handled.

This subsection discusses the significance of each of the individual elements that make up the total cost avoidance potential and the likelihood that cost reduction actions relative to each element can be achieved.

Wastebasket Ownership. As seen in Table 3, the ratio of the number of wastebaskets emptied in August 1977 to the number emptied in February/March 1977 is 0.75, which would correspond to a reduction of 25 percent. This means that 25 percent of the wastebaskets could be eliminated. Based on the range of values of N, a reduction of 26 to 34 percent in the required number of wastebaskets would be predicted.

The minimum number of wastebaskets required can be more dependent on placement factors for convenience of office personnel and number of rooms then on the quantity of work handled. Consequently, one would expect that, for practical reasons, the achievable reduction will generally be somewhat less than would be predicted based on the value of N alone.

It is important to note that wastebasket ownership savings results from a decrease in future hardware procurement and/or repair. Consequently, this savings will not be immediately realized unless the reduced number of wastebaskets resulting from source separation is equal to the number already exhausted by old age.

Janitorial Collection Labor. If a recycling program is implemented so that the office waste flow quantity is reduced, then the time required by the janitors to collect and transport the disposable waste to the outdoor container would be reduced. The obvious reduction, seen in Table 3, is the reduced number of runs to the outdoor container (from 15 for Phase I to 11 for August 1977 of Phase II, which equals a reduction of 27 percent). The number of wastebaskets emptied was also reduced 25 percent, as discussed earlier. It is important to note that the end test data of Phase II was greatly affected by heavy rains. The reduction in the number of runs to the outdoor containers is believed to be directly attributable to the rain. It is assumed that the janitors did not empty all the wastebaskets they could have because it would have required more trips outside. They also probably packed their portable mobile containers more densely than usual to avoid many trips outside in the inclement weather. Consequently, the end test data of Phase II bears little resemblance to normal janitorial operation.

The janitorial cost* reduction potential using Equation (6) was estimated to be \$15,355 to \$20,079 per year for $N = 0.26$ and 0.34, respectively. The measured janitorial cost during Phase I was \$59,056 per year, as shown in Table 11. The annual janitorial cost in Phase II was equal to \$38,113 for office refuse collection. The difference is \$20,943, which is very close to the estimated value for $N = 0.34$.

It is important to note that the additional time made available to the janitors must be constructively used by the facility, or the contracted cost per square foot for janitorial refuse collection must be reduced if the savings are to be realized. If this time is spent handling the recyclable materials, the cost must be accounted for in the recyclable materials economic analysis.

Outside Container Ownership and Maintenance. These bins are large (at Vandenberg Air Force Base, they are either 6 or 10 cubic yards each), and they are designed specifically for collection by the refuse collection trucks. If it is assumed that source separation of office waste will continue and that the original number of outdoor containers prior to source separation was the optimum cost effective quantity for that waste flow, then the number of containers should decrease to cost effectively match the reduced flow of disposable refuse. From Table 26 of Reference 2, there are 217 of the 10-cubic-yard containers and 119 of the 6-cubic-yard containers at Vandenberg Air Force Base. These units handle 78.5 tons of refuse (average) per week, or 0.027 ton per cubic yard of container per week. If six tons of office waste is pulled out of the flow, approximately 22 of the 10-cubic-yard containers or 37 of the 6-cubic-yard containers, or some combination of the two, could be removed from the waste stream without adversely impacting the storage capacity. To maintain adequate collection service, this should be done at sites served by more than one container or at locations where two or more buildings could conveniently share one container. During the test at Vandenberg Air Force Base, no outdoor containers were pulled out of the system and as a result no savings were realized.

*The janitorial cost summary for Vandenberg Air Force Base office buildings is given in Table 12.

TABLE 12. SUMMARY OF VANDENBERG AIR FORCE BASE OFFICE BUILDING JANITORIAL SOLID WASTE COLLECTION COSTS(1)

Bldg No.	H_t m-hr/day	A_t/A_T (2)	A_T sq ft	H_T (2) m-hr/day	C_T (3) \$/mo	$C_T H_t$ \$/mo m-hr/day	$A_t H_T$ sq ft m-hr/day	R (4) \$/ft^2-mo
PHASE I - February/March 1977								
10577	0.38	1/3	79,757	14.25	1,593.63	605.58	378,846	0.00160
7000	0.93	0.175	171,388	32	4,137.50	3,847.88	959,773	0.00401
8500	1.00	0.315	126,000	16.5	3,326.40	3,326.40	654,885	0.00508
6525	0.32	0.130	128,025	20	3,399.12	2,821.27	332,865	0.00848
861	0.32	1	11,290	2.75	298.06	95.38	31,048	0.00307
							$\frac{\Sigma C_T H_t}{\Sigma A_t H_T}$ (4)	= 0.00454
PHASE II - August 1977								
10577	0.27	1/3	79,757	14.25	1,593.63	430.28	378,846	0.00114
7000	0.49	0.175	171,388	32	4,137.50	2,027.38	959,773	0.00211
8500	0.87	0.315	126,000	16.5	3,326.40	2,893.97	654,885	0.00442
6525	0.42	0.130	128,025	20	3,399.12	1,427.63	332,865	0.00429
861	0.41	1	11,290	2.75	298.06	122.20	31,048	0.00394
							$\frac{\Sigma C_T H_t}{\Sigma A_t H_T}$ (5)	= 0.00293

continued

TABLE 12. CONTINUED

Bldg No.	H_t m-hr/day	A_t/A_T (2)	A_T sq ft	H_T (2) m-hr/day	C_T (3) $/mo	C_TH_t $/mo m-hr/day	A_tH_T sq ft m-hr/day	$R^{(4)}$ $\$/ft^2$-mo
PHASE II - February/March 1978								
10577	0.22	1/3	79,757	14.25	1,593.63	350.60	378,846	0.00093
7000	0.59	0.175	171,388	32	4,137.50	2,441.13	959,773	0.00254
8500	1.06	0.315	126,000	16.5	3,326.40	3,525.98	654,885	0.00538
6525	0.36	0.130	128,025	20	3,399.12	1,223.68	332,865	0.00368
861	0.23	1	11,290	2.75	298.06	68.55	31,048	0.00221
							$\frac{\Sigma C_TH_t}{\Sigma A_tH_T}$ (5)	= 0.00323

NOTES:

(1) The method used to determine the janitorial solid waste collection costs, and the significance of the notation used, are discussed in Reference 2. For the data presented above, the janitorial coverage considered was limited to that which was common to all three surveys.

(2) Data from custodial contractor, B&W Services, Inc.

(3) Data from Table 22 of Reference 2.

(4) $R = C_TH_t/A_tH_T$.

(5) The average R for each survey was determined as shown (rather than by using a simple average of the figures in the last column) to avoid equal weighting of the data without regard for the square footage serviced. Even though considerable care was taken to calculate R, it is important to note that only three values were determined, one for each survey. Consequently, these values are subject to error and must be interpreted strictly as cost approximations.

It is also important to note that container savings are in hardware and, unless the reduced number equals the number exhausted by old age, the savings would not be immediately realized.

Truck Collection Labor. The truck collection labor force consists of one supervisor and six drivers, plus a military helper who provides 70 percent of his time. According to Reference 2, this annual labor force costs $100,757.00 per year. This cost is assumed to be a direct function of the number of bins requiring service and the waste flow rate. If the number of containers is reduced in proportion to the decrease in waste flow, then collection labor cost should also be reduced by the same proportion. It is important to note, however, that the savings can be realized only if the labor time made available is constructively used elsewhere. For example, if the total waste flow is reduced by 12 percent, then four of the drivers should be pulled from waste collection for one full day each week (i.e., 4 man days ÷ (6 men x 5 days + 0.7 men x 5 days) = 11.9 percent). Otherwise, it might prove to be difficult to utilize 12 percent of all the personnel labor on a daily basis when available. During the Vandenberg Air Force Base experiment no outdoor containers were pulled and, consequently, no truck collection labor savings were realized.

Collection Truck Ownership and Maintenance. Using the vehicles listed in Table 1 to collect the solid waste incurs a number of expenses, including vehicle acquisition, depreciation, and maintenance. Table 25 of Reference 2 indicates that the average vehicle life is 8 years. Mobile equipment, such as refuse trucks, can have a cost effective life of 10 years (Reference 7). If it is assumed that the 2-year decrease of Vandenberg Air Force Base vehicle life is caused by more-than-average weekly use (i.e., miles driven and bins serviced), then up to 20 percent reduced waste flow and number of containers would simply add life to the vehicles without adding to the vehicle cost per ton. As a result, the annual cost avoidance would, like container and labor cost, be proportional to the decrease in outdoor containers. Again, because no outdoor containers were pulled out of the system, the truck time studies did not show a decrease in collection time.

Landfill. Table 27 of Reference 2 shows the cost breakdown of operating the Vandenberg Air Force Base landfill. The annual equipment costs are $42,640 and the annual labor costs are $34,547, from which the costs per ton are $5.18 for labor and $6.39 for equipment to dispose of 6,671.6 tons of solid waste per year. Land use cost for disposing the refuse was calculated to be $0.13 per ton in Reference 2. These costs are high when compared to the sanitary landfill operating costs given in Reference 8; according to this reference, an annual generation rate of 6,671.6 tons is equivalent to a waste generating civilian population of 10,000 people, which has a minimum landfill operation cost of $1.80 per ton. This cost includes wages which ordinarily are 40 to 50 percent of the total operating costs, equipment which equals 30 to 40 percent, and miscellaneous items which make up the remainder. At Vandenberg Air Force Base the equipment costs are more than labor. Reference 8 indicates

that the cost of operating two small machines is significantly more than that for operation of a larger single machine with equal capacity. The high percentage at Vandenberg Air Force Base for equipment is believed to be due to operating two machines rather than one.

In regard to landfill cost avoidance due to source separation, Civil Engineering Laboratory believes that the disposal cost per ton should not change significantly with a relatively small disposal rate reduction. However, because the rate reduction derived from the source separation was so small compared to the total base generation, actual savings could not be measured for comparison to estimates based on Equations (18), (21), and (24).

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SECTION VI

CONCLUSIONS

1. Source separation effectiveness data varied with the commodity (refuse category) separated, and with the source (person, family, or office personnel) responsible for the actual separation. Computer cards were the most effectively separated (92 to 95 percent), probably because they are used only in stacks and are discarded as stacks. The effectiveness of separating computer printout was moderate (43 to 69 percent). This commodity is used in smaller batches and may be used by individuals at their desks who may then discard them in small stacks without remembering or bothering to keep them separate from the general waste.

The overall effectiveness for office buildings (42 to 52 percent) was lower than for residences (43 to 88 percent), partly because the major paper product from an office, white ledger, requires more effort or diligence to assure separation. Families are more accustomed to stacking and saving newspapers, which rated the second highest in effectiveness (83 to 91 percent), while they have not been as accustomed to saving their aluminum cans. The effectiveness rating for cans, however, showed an increase from 13 to 14 percent in August 1977 to 31 to 33 percent in February/March 1978.

2. Separation effectiveness data derived using the photo-sort technique appear reasonable, in that the results (i.e., separation effectiveness shown in Tables 8 and 9) consist of trends that are not highly variable. Because the container photographs were taken at various times during the day for each monitored container to look at different levels, more accurate data were used to fractionate the solid waste stream by constituent mass. This procedure decreased errors caused from undiscovered materials buried beneath the surface as would more often occur with a single photograph.

3. The cost avoidance equation presented in this report is believed to be unique in that it is the first known attempt to analytically estimate the cost savings of office refuse handling due to a reduced waste flow rate. The cost savings estimated for the annual janitorial waste handling using this equation are in close agreement with the measured results ($20,079 estimated versus $20,943 measured) using the 34 percent waste reduction percentage. However. because there was a small scale source separation program being implemented before the large scale system being addressed by this report, Civil Engineering Laboratory was unable to determine if 34 percent is the correct percentage or if 26 percent should be used. It is believed that the cost avoidance for the containers

and truck collection was not realized during the Vandenberg Air Force Base experiment because the potential reduction in outdoor containers was not implemented. Consequently, this portion of the equation was not verified quantitatively. The expected normal variation of the weekly waste tonnage deposited at the landfill was as much as the recyclable material tonnage pulled from the stream. An increase of 8.1 tons of refuse materials was generated in August 1977 over February/March 1977 for office and residential alone which is approximately one-half of the total base, as compared to a total 6.33 tons of recyclable materials pulled out of the stream. As a result, the landfill cost avoidance could not be adequately measured to compare its data to the equation.

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